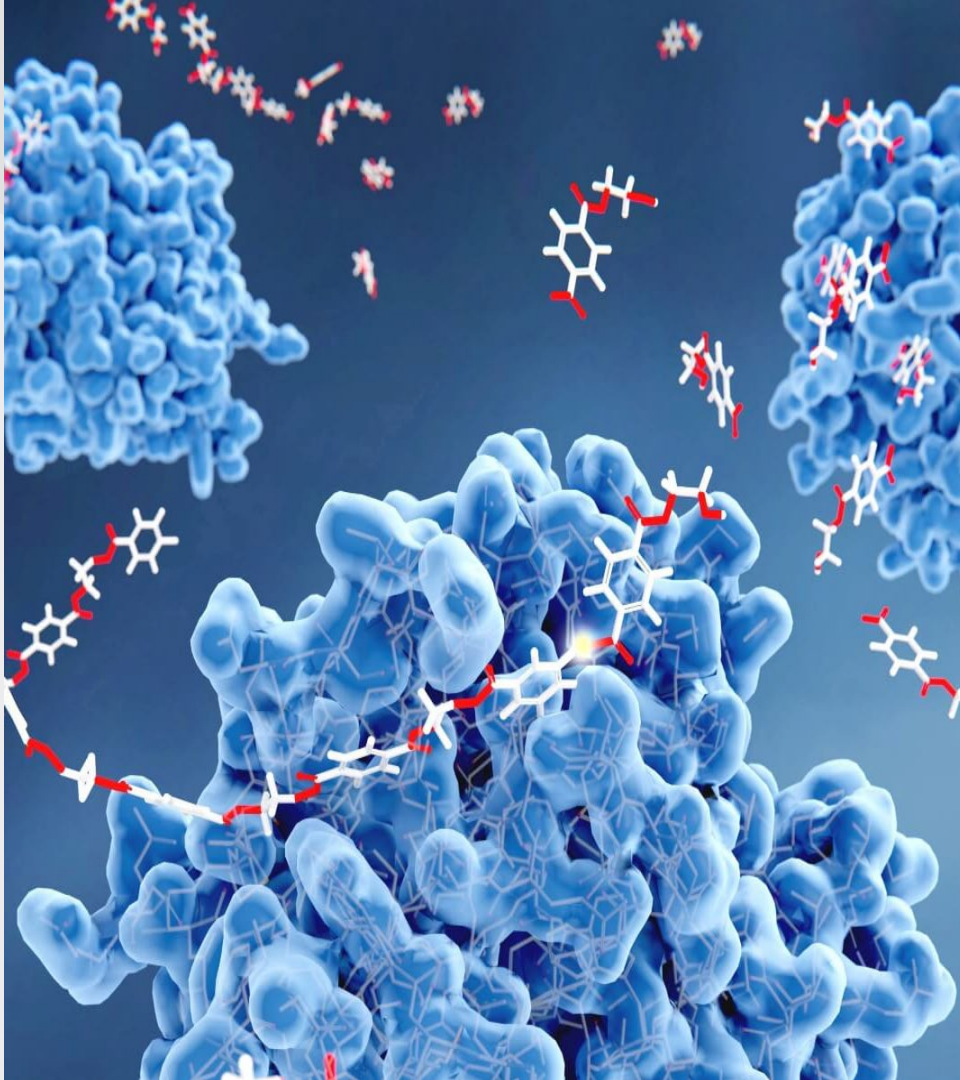
Chapter 3: Enzymes

H2 Biology



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Introduction

Enzymes, are also known as **biological catalysts**, since they **catalyse biological reactions.**

While most enzymes are **globular proteins**, some are RNA molecules known as **ribozymes**.

They are important as many metabolic reactions, though spontaneous, **occur at a very slow rate**.

Thus, **enzymes are needed to speed up these reactions**.

Enzymes are usually classified according to the type of reaction they catalyse and they can be named according to their substrates (i.e. reactants that enzymes act on).

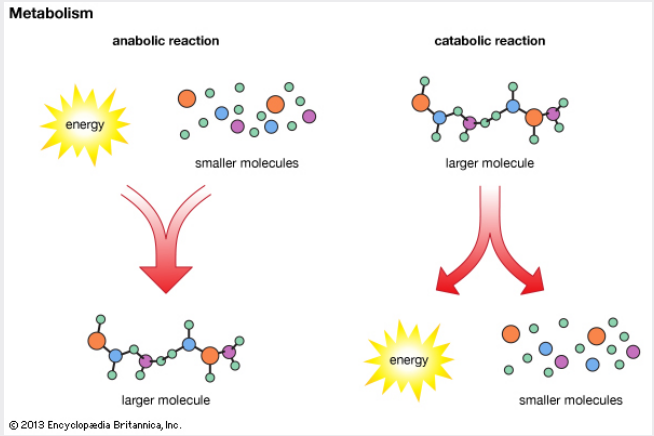
Introduction

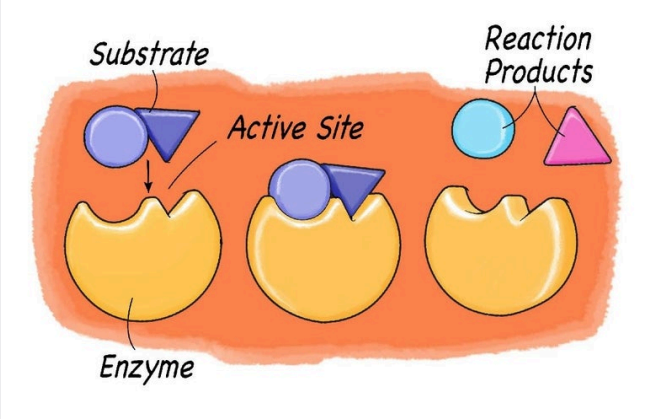
Enzymes are defined as **biological catalysts** which **speed up the rate of metabolic reactions** (both catabolic and anabolic) while **remaining chemically unchanged at the end of the reaction**.

Catabolic Reactions – The breaking down of complex molecules into simpler ones.
Anabolic Reactions – The building up of complex molecules from simpler ones.

Common Enzyme Properties:

1) Highly specific
2) Effective in small amounts with high turnover rates
3) Remain chemically unchanged at the end of the reaction
4) Affected by certain factors, e.g. temperature, pH, substrate and enzyme concentration
5) May require cofactors to function
6) Activity is tightly regulated
7) Allow reactions to reach equilibrium in a shorter time



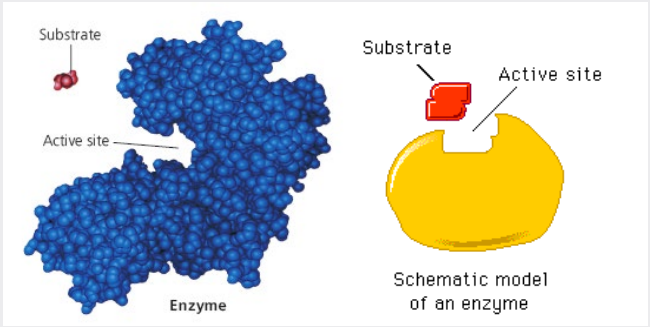


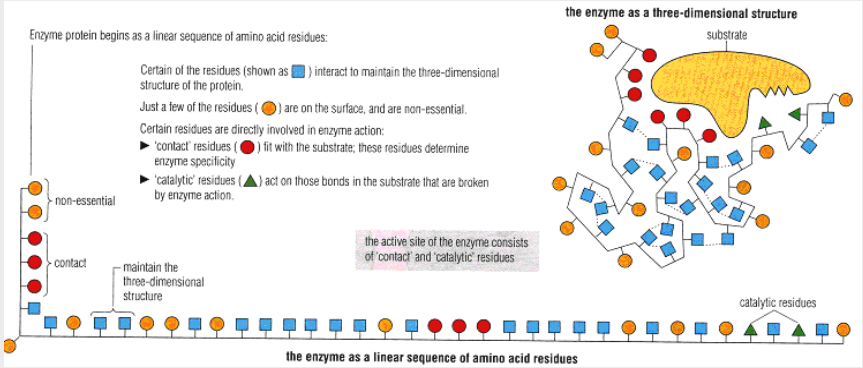
Introduction

Enzymes have a **unique three-dimensional conformation** with an **active site** (i.e. **catalytic site and substrate-binding site**) of the enzyme.

The **active site** is **formed by 3 to 12 amino acids** from different parts of a single polypeptide chain held together by **hydrogen bonds, ionic bonds, disulfide bonds and/or hydrophobic interactions.**

Other amino acids are involved in **maintaining the overall three-dimensional structure** of the enzyme.



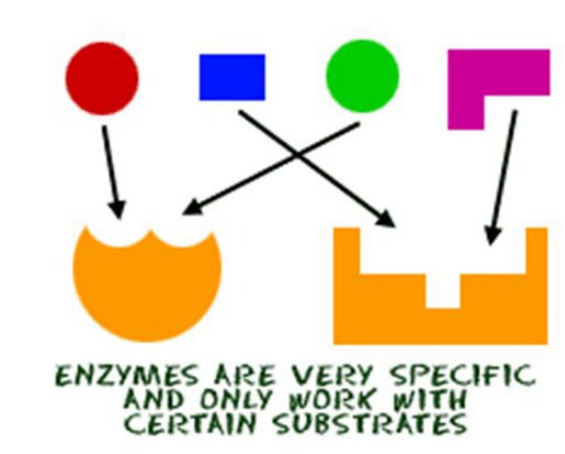


Introduction

The **enzyme specificity** is determined by the **fit between the shape of the enzyme's active site and its substrate.**

The active site of an enzyme is **complementary to its substrate in terms of shape, size, charge and orientation.**

Enzymes are specific to only **one particular substrate** or **one group of similar substrates** e.g. lipases hydrolyses only lipids.



Introduction

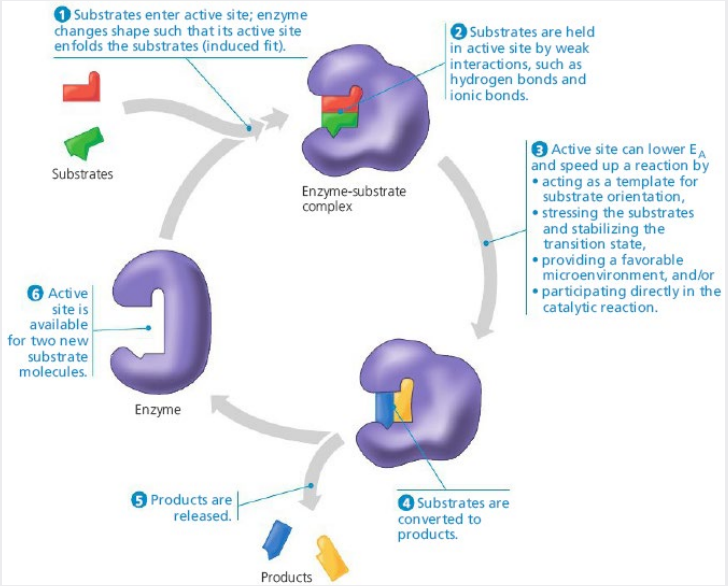
Substrate binding to the enzyme active site results in the formation of the **enzyme-substrate complex** (E-S complex).

The substrates are held in the active site by **weak bonds** such as **hydrogen bonds, ionic bonds and hydrophobic interactions.**

The active site (catalytic site) catalyses the **conversion of substrate to product.**

Once the products are formed, they are no longer complementary to the active site and thus, will leave the enzyme.

The enzyme is then available to act on other substrates.



Introduction

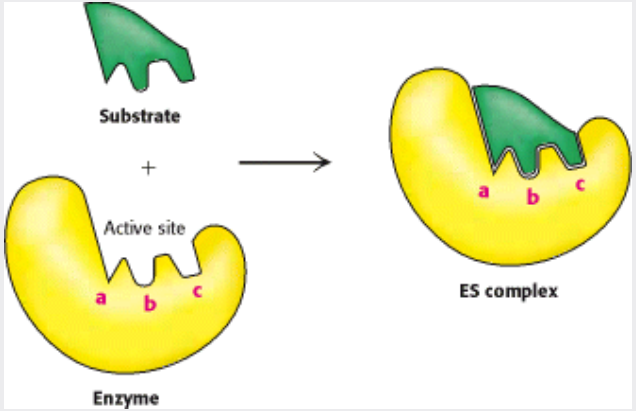
Two hypotheses explain how enzymes function.

1) **Lock & Key Hypothesis**:
   The **enzyme acts as a lock** and the **substrate acts as a key**, which fits precisely.

   The active site of the enzyme is **perfectly complementary** to the substrate in terms of shape, size, charge and orientation.

   The substrate binds to enzyme's active site to form the enzyme-substrate complex.

   This mode of activation is more probable for enzymes that work on only one type of substrate.



Introduction

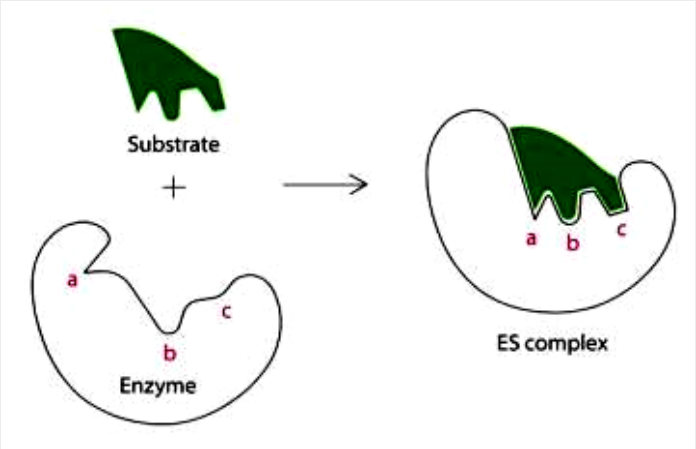
2) Induced Fit Hypothesis:

Enzymes may work in a more flexible manner.

The active site is **not perfectly complementary** to the substrate in terms of shape, size and orientation.

However, upon forming some bonds with the substrate, the enzyme changes its shape, which **leads to a precise fit to form the enzyme-substrate complex**.

This mode of action is more probable for enzymes that work on a group of closely-related substrates, e.g. lipases.

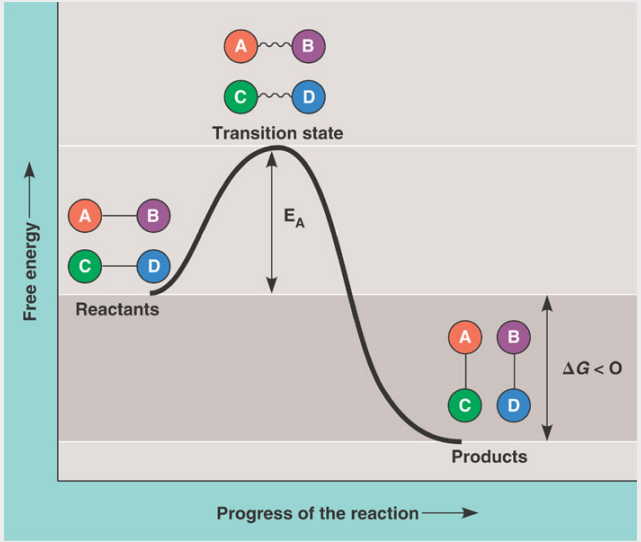


Introduction

Activation energy (E_A) is the **initial investment of energy** that reactant molecules must possess to overcome an energy barrier, in order for a reaction to begin.

Enzymes speed up biological reactions as they provide an **alternative pathway**, which has a **lower activation energy (E_A)** as compared to the uncatalysed reaction.

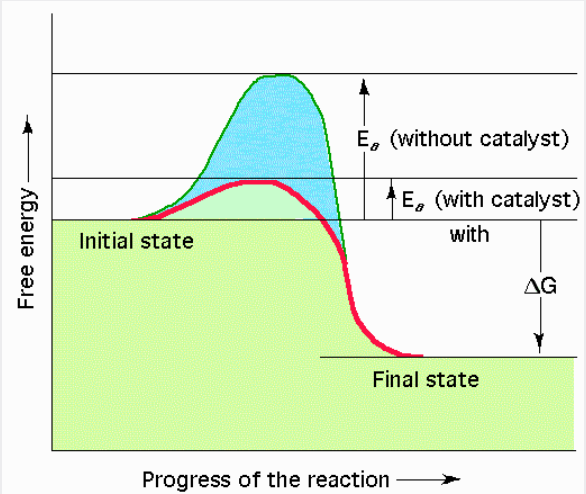
Thus, **more reactant molecules possess energy equal or more than the activation energy required for the catalysed reaction**. As such, the reactions occur at a faster rate and a high temperature is not required.



Introduction

Enzymes lower the activation energy of a reaction by **promoting formation of transition state** via a number of mechanisms, such as:

- Allowing **close proximity** of reactants due to temporary binding of substrates on the enzyme;
- Ensuring **correct orientation** of reactants to facilitate the reaction taking place;
- **Destabilising the bonds of reactants** as enzymes contort reactant molecules to facilitate formation of transition state;
- Providing a conductive microenvironment for reaction



Enzyme Kinetics

Enzyme kinetics is the study of the **rate of chemical reactions** that are catalysed by enzymes. The study of an enzyme's kinetics reveals the catalytic mechanism of this enzyme, its role in metabolism, how its activity is controlled, and how other factors might affect the enzyme.

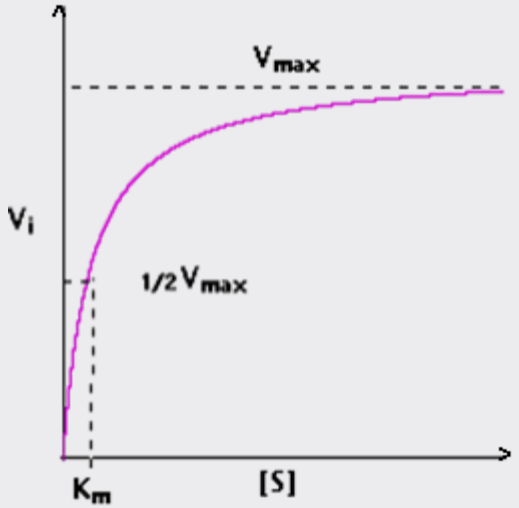
The reaction rates of enzymes can be measured by:

- the amount of **product formed per unit time**
- the amount of **substrate depleted per unit time**

The **Michaelis constant** or **K_m** of an enzyme is the:

- **substrate concentration** at which the **rate of reaction catalysed by the enzyme equals to half its maximum rate** (i.e. ½ Vmax).

- indication of the affinity of the enzyme for its substrate molecules i.e. how readily the enzyme reacts with its substrate.

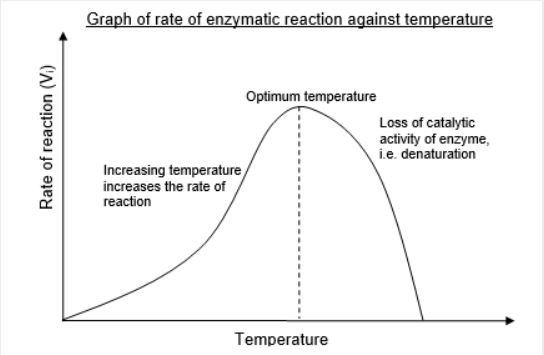


Factors Affecting Enzyme Activity

Enzymes are affected by factors such **as substrate concentration, enzyme concentration, temperature and pH.**

Temperature:

- Increase in temperature will increase the kinetic energy of the substrate and enzyme molecules.
- Increase in temperature affects the stability of the protein structure.
- This results in an asymmetrical graph with an optimum temperature whereby the rate of enzyme reaction is at its maximum.
- Different enzymes have different optimum temperature

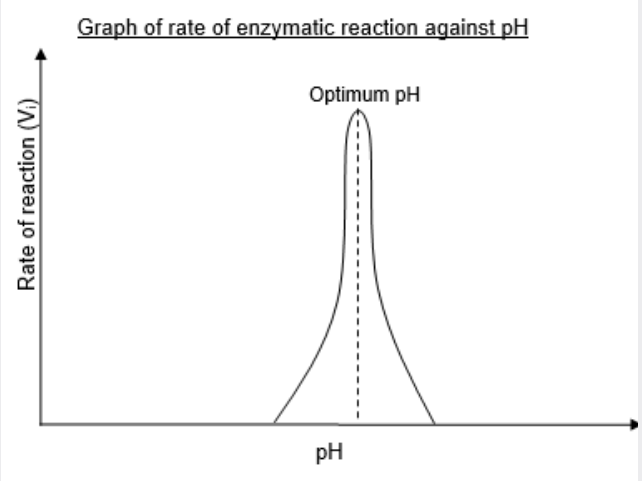


Factors Affecting Enzyme Activity

Enzymes are affected by factors such **as substrate concentration, enzyme concentration, temperature and pH.**

pH:

- Enzymes function effectively over a narrow pH range.
- Each enzyme has an optimum pH at which it functions most efficiently.
- Unlike the effects of heat on enzymes, the effects of pH are usually reversible, within limits. Restoring the pH to the optimum level usually restores the rate of reaction.



Enzyme Inhibition

Enzyme activity can be **reduced by inhibitors**.

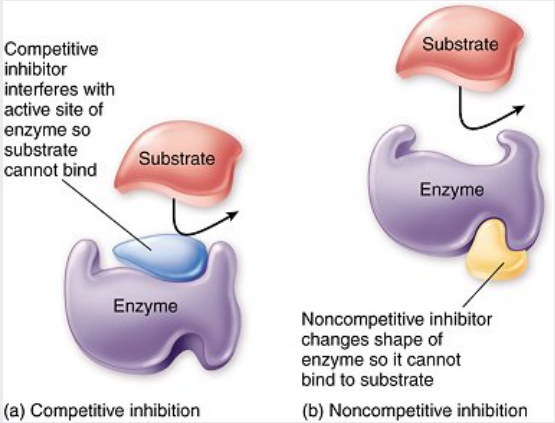
This can be achieved by the formation of **enzyme-inhibitor (E-I) complex**.

There are two main types of inhibition: **competitive and non-competitive inhibition.**

Competitive inhibitors are **structurally similar** (in terms of shape, size, charge and orientation) to the **substrate molecule**.

They **bind to the active site of the enzyme** and thus **competes with the substrate for the active site.**

Therefore, they **reduce the number of active sites available** for the substrates to bind and form enzyme-substrate (E-S) complex.

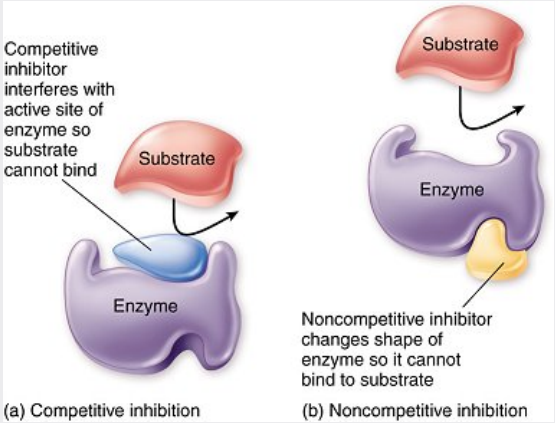


Enzyme Inhibition

Non-competitive inhibitors are **not structurally similar** (in terms of shape, size, charge and orientation) to the substrate molecule.

They bind at a **site away from the active site.**

This interaction **alters the specific 3-dimensional conformation** of the enzyme molecule such that they **active site is distorted** and no longer complementary to substrate, thus **not able to bind to the substrate properly** or the substrate can still bind to active site but the **enzyme is not able to catalyse the conversion of substrate to product.**



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